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Enhancing bus transit service efficiency under conditions of high street congestion

L V Bulavina, L A Bannikova, A R Mukhametgaliyeva

Urban Development Department, The Urals Federal University named after the first Russian President B. Yeltsin (URFU), 17, Mira St, Ekaterinburg 620002, Russia

E-mail: muhametgaliyeva03@gmail.com

Abstract. The article is devoted to solving the problems of transport services for residents of the city of Yekaterinburg. The authors consider public transport as one of the important solutions to the transport problems of the city. This work analyses speed and time characteristics of bus transit services in high- traffic main streets in the city of Ekaterinburg. It also defines structure and duration of delays on route, share of general route duration, travel speed on route runs and general service speed. Foreign experience in bus transit services has been analysed. This work proposes measures to improve the service accessibility for remote residential districts with use of BRT system. It also includes measures to improve bus transit services in Ekaterinburg and assessment of their expected efficiency.

1. Introduction

Increase in the level of automobilization in Russian cities has brought about excessive pressure on streets caused by grown number of vehicle transit, congestions and speed decrease for all traffic participants. Public transit loses its attractiveness as it moves in general traffic flow and is less comfortable than a car.

For the last years, enhancement of the public transit efficiency has become a matter of great urgency in Russian cities. Development of public transit as a top priority started fairly recently.

As the world tendency is to pay more attention to improvement of public transit and creation of conditions for comfortable city environment, Russian cities have also changed their attitude to public transit and started taking active measures to improve the passenger service quality.

Exerting influence on low efficiency of traffic operation are imperfect traffic organization, obsolete vehicles in use, low passenger carrying capacity of existing buses, route duplication and numerous traffic jams on route and on stops. All the above decrease service quality and result in lower comfort for passengers.

Since recently, the policy of transport development in cities have changed greatly in favour of public transit. For example, such authors as A.R. Rakhmatullina, D.S. Dudakov and A.A. Kass, in their articles, emphasize the role of public transit in the development of contemporary cities, and, besides, show examples of new innovative technologies in the sphere of passenger service [1]-[5]. Methods of organization of public transit on priority-traffic basis are under active research [6]-[14]. In book ‘Transport in Cities Comfortable for Living’ V.Vuchik insists that a bus transit system enjoying dedicated bus lanes and priority in traffic will ensure excellent level of service and need much lower investments than those required to build a new rail transport system [15].



In many foreign countries, the public transit is comfortable and accessible. For example, in some countries metrobuses or BRT are available as a way of bus transit organization, where buses move at higher speed and are of higher passenger carrying capacity.

The BRT system is in use in 171 cities of the world. Length of the lanes throughout the cities is 5,145 km [16]. These figures persistently grow, as there emerge more and more cities introducing the BRT system. The advantage of BRT system is its lower construction costs, being 10 times less than to build an underground railroad.

The BRT system enables to ensure a peak traffic rate on high-street routes for 60 to 70 units per hour and, consequently, a carrying capacity of 15 to 20 thousand passengers per hour. Such approach will provide for BRT system attractiveness and comfortability to passengers [17].

To our regret, there are no systems built-up on BRT principles in Russia and CIS countries. Proposals to build-up such system have been put forward in some cities, but none of them has been implemented. For example, the city of Ufa used to hold talks with representatives of Istanbul having its BRT system in active operation. The city of Astana started to implement the BRT system on the way connecting the EXPO town and the airport, but its construction was not completed.

In Russian cities, the main measure taken to provide priority to motor vehicle transport is earmarking of the lanes for bus and trolleybus traffic on short runs of the streets, which is not sufficient for bus traffic.

2. Analysis of street-and-road network and high-street load level

According to the instructions for organization of priority public transit service, the main conditions for allotment of dedicated lanes for public transit are the level of load ($z > 0.7$), number of traffic lanes ($n > 3$), and public transit traffic frequency ($N > 40$ units/hour) [18]. To select a part of the street feasible for measures to organize a public transit priority traffic, the main criteria have been analysed.

To identify the core high-street routes featuring the highest bus and trolleybus traffic frequency, a traffic frequency pattern was drawn-out, being based on the average traffic intervals in rush hours. Eventually, there were defined the following streets: Malyshev, Lenin, 8-Marta, Belinsky, Scherbakov, Karl Liebknecht, Sverdlov, Wilhelm de Genin and Bardin streets, where the traffic frequency varied from 31 to 105 units per hour. On most routes in the above streets, the public transit buses were of low carrying capacity.

The traffic way widths in high streets were analysed and a map was drawn out of the streets, where it appeared potentially possible to organize dedicated lanes without the need to re-construct them (Figure 1). As a result, the feasible streets became the following: Sverdlov, Scherbakov (between Lyzhnikov and Samoletnaya), Schorsa (between Moscovskaya and Belinsky), Malyshev and Lenin Avenue [18-19].

3. Field testing of bus traffic indicators in the central part of Ekaterinburg

Field tests of the bus traffic were carried out in five high streets, involving measurement of the key traffic time characteristics during morning rush hour (from 8-00 to 9-00 a.m.) in the direction to the centre of the city and evening rush hour (from 18-00 to 19-00 p.m.) from the centre. Measurement of delay duration included: breaking start time before a stop, duration of full stops, doors opening and closing and that of driving out of the bay. On the move, the measurements covered the time of stopping and starting-up in traffic jams and nearby traffic lights. The causes of delays were subject to thorough consideration. For the field tests, the high streets featuring the most intensive public transit frequency we selected.

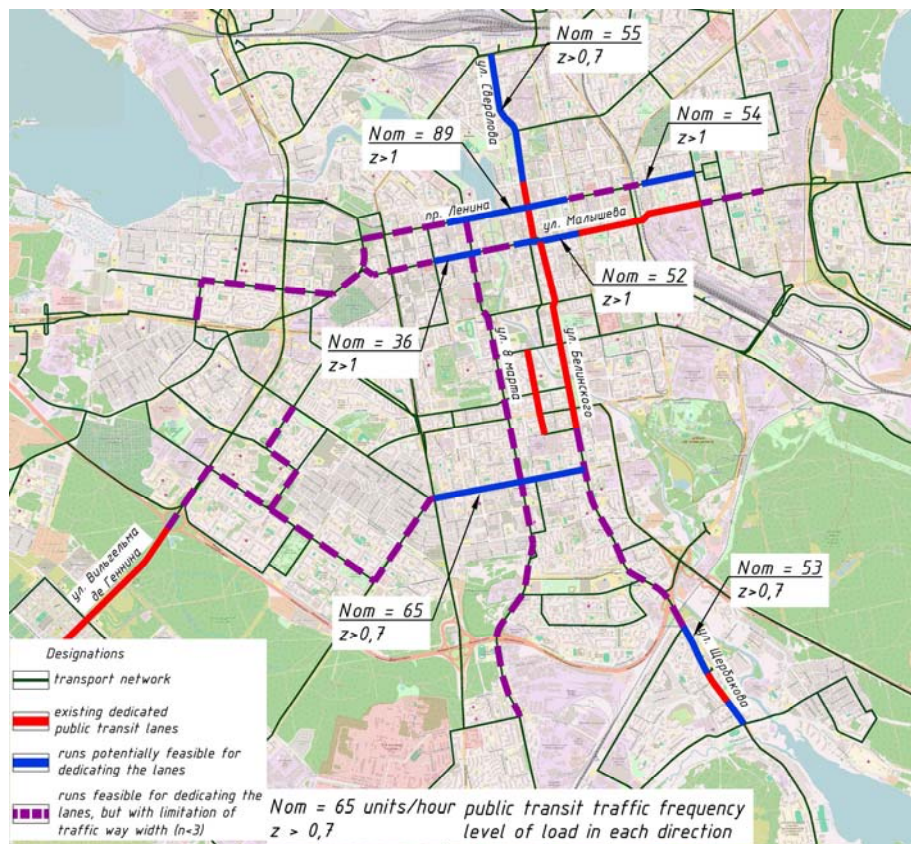


Figure 1. Map of street runs, where it seems feasible to dedicate public rapid transit lanes.

4. Analysis of bus traffic operation and assessment of its efficiency

We analysed delays within the structure of the whole traffic duration, as well as causes of delays and their duration. For each of route runs we calculated the traffic speed and travelling speed in morning and evening rush hours. In 8-Marta St, the travelling speed on some lengths was 12.9 to 17.5 km/h in the morning rush hour, and much lower, i.e. 11.3 to 14.2 km/h, in the evening one.

According to the test results, in the morning rush hour the delays exceeded 50% of the whole ride duration in most cases. A considerable percentage of delays was due to waiting for the traffic pacer. Shown below are the consolidated data on traffic speeds in the streets under issue. The traffic speed, i.e. the average speed of a passenger's ride on the tested run of the street including delays, as represented in Table 1, is the evidence of low efficiency of the bus traffic.

The test results show that the most intensive routes in the centre of the city are in wide main streets – Lenin Avenue and Malyshev St. Their traffic speeds are similarly low during both evening and morning rush hours.

Table 1. Traffic speed.

Street name	Length of the run, km	Traffic speed, km/h	
		Morning rush hour	Evening rush hour
8-Marta	3.0	14.3	9.96
Belinsky-Rose Luxemburg	2.7	13.5	8.4
Lenin	5.0	10.7	7.02
Malyshev	5.2	11.0	6.8

Based on the test results, the following main causes of bus delays during morning and evening rush hours were identified:

- jams on the stops due to great number of transport facilities;
- long waiting before traffic lights in case of stops located before a crossroads (transport facilities waiting for a traffic pacer impeded the bus to leave and change lanes);
- while leaving a stop bay there emerged a difficulty to change lanes due to unfair practices of some drivers (they did not yield right of way to buses, despite the traffic rules);
- the vehicle capacity of most crossroads in the centre of the city was up to their capability

The test results enabled to calculate the maximum possible traffic speed excluding delays caused by traffic jams, but including minimum delays nearby traffic lights. Given that, the implementation valuation multiple was applied as determined by the following formula 1:

$$K_v = \frac{v_{act}}{v_{max}} \quad (1)$$

where K_v – is the valuation multiple, v_{act} - is the actual traffic speed, km/h, v_{max} - is the maximum possible traffic speed excluding delays caused by traffic jams, but including minimum delays nearby traffic lights, km/h

Table 2 shows the summary data on the traffic speed in the streets under issue, in morning rush hour. The test results show that the buses use only 60-70% of possible traffic speed during morning rush hour, except for Schorsa St being less intensive, where the buses use 84% of the possible speed.

Table 2. Bus traffic speed in central streets in morning rush hour.

Street name	Actual speed, km/h	Maximum possible speed, km/h	Implementation multiple, K_v of speed
Malyshev	11.0	16.9	0.65
Lenin	10.7	14.4	0.74
8 Marta	10.7	17.1	0.62
Belinsky	13.5	18.6	0.73

This means that the public transit system functions with time and economic outlays in Ekaterinburg. As at higher traffic speed, there will be increase in motor vehicle turnover, efficiency per motor vehicle unit and number of passengers transported, so the time outlays for passenger transit could be at least 1.5 times less. To reduce the time for bus transit traffic it is required to take a complex of both regulating and planning measures.

5. Measures to ensure bus transit traffic to remote districts

Having analysed foreign best practices we come to a conclusion that the BRT system is a rapid transit system with higher carrying capability that requires less time and capital investment than for construction of an underground railroad. Therefore, it seems reasonable to use the BRT system instead of building underground railroads in order to ensure connection between remote districts and the centre of the city. In Ekaterinburg, there emerge new remote residential districts, among them Academichesky and VIZ-Pravoberezhny (Figure 2). To ensure fast and comfortable connection of the districts with the centre of the city it is reasonable to build rapid bus corridors.

Residential district Academichesky is located in the south-west of the city. In 2019, the district population was 80 thousand and the plans are to carry on its further development and construction. In the district, there exist key social infrastructure facilities (polyclinics, kindergartens, schools), but there are no other job opportunities beyond them. Owing to that, the district faces problems with transport services. There are two streets allowing entry in and exit from the district and connecting it with the centre of the city. Therefore, there observed regular traffic jams. The public transit services include 11 bus routes, of them, 18% are of high carrying capacity, 73% - of medium and 9% - of low

one (minivans). The public transit cannot cope with the passenger transportation during rush hours. Given that, almost 70% of people ride in own car.

According to the territorial planning documentation, there is a corridor reserved for future tramway to/from Akademichesky, but its construction is dragged on due to lack of funding. It seems reasonable to use the corridor for arranging the BRT-based bus lane there. In future, since the trams traffic is to be of low frequency, joint trams and buses (on the dedicated lane) traffic will be possible, i.e. following the example of Ligovsky Avenue in St-Petersburg.

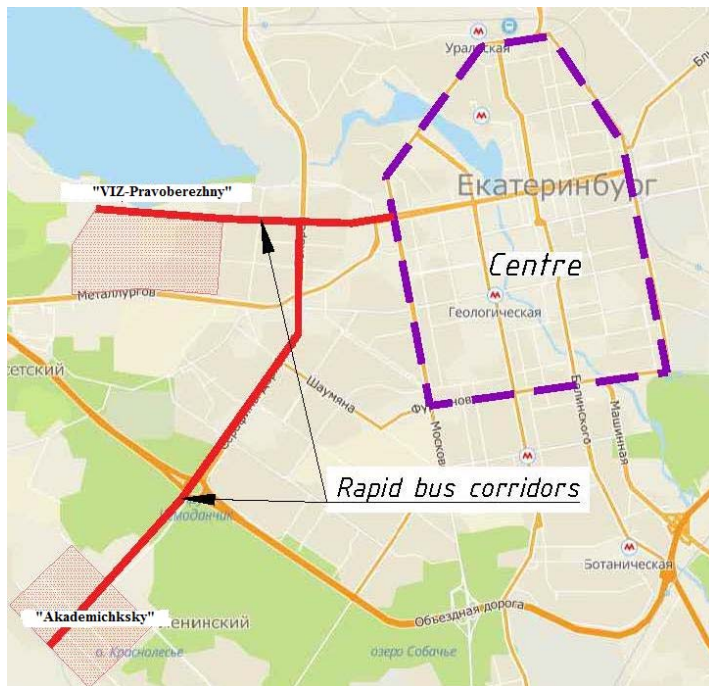


Figure 2. Proposals for building rapid bus lanes.

Alongside with building-up the rapid bus transit system in order to increase efficiency of public transit operations, there was a measure proposed - as a low-cost measure at the initial stage - to arrange for dedicated lanes and provide priority to public transit. Within the framework of the project to build-up a system of dedicated lanes for motor vehicle transit in Ekaterinburg, there planned to arrange dedicated lanes in Schorsa St and Amundsen St [20]. This corridor will connect Akademichesky and South-West districts to the central high streets: 8-Marta St and Belinsky St. According to the Master Plan of the city, the private house building territory adjacent to Amundsen St and Moscovskaya St is to be replaced with multi-storey housing buildings, which will obviously add pressure on adjacent street-and-road network.

Within the work we analysed efficiency of dedicated lanes for public bus transit in Schorsa Street, being an initial part of the dedicated lane network in Schorsa St to Amundsen St. Nowadays, there traced two traffic routes: route 1 - in the part between Moscovskaya St and Belinsky St only and route 2 - along the whole length from Moscovskaya St to 8-Marta St.

To calculate efficiency of the proposed measures, we carried out the traffic simulation with the use of software complex PTV Vision VISSIM, taking into account the project solutions for morning and evening rush hours. A comparative assessment of the indicators was carried out, i.e. travel duration, speed, delays without dedicated lanes for bus transit and delays in case of dedicated lanes as obtained from simulation. The results shown in Table 3 confirm a considerable possible reduction in travel duration and increase in traffic speed.

Table 3. Efficiency of dedicated lane operation in schorsa st between Moscovskaya St and Tchaikovsky St during morning rush hour.

	Without dedicated lane	With dedicated lane	Effect (reduction in travel duration)
Travel duration, min		Moscovskaya St – 8-Marta St	
	10:05	5:33	45%
		Moscovskaya St – Belinsky St	
	10:26	7:27	28%
Traffic speed, km/h		Moscovskaya St – 8-Marta St	
	6.7	12.1	81%
		Moscovskaya St – Belinsky St	
	10.8	15.1	40%

6. Conclusions

At present, streets in the cities are overloaded with motor vehicles. The surface public transit vehicles moving in a common flow suffer from long delays on route and low speed. One of the reasons causing excessive pressure on high-street traffic is development of new residential districts in the outskirts. The problem is that there is a limited number of jobs therein, while in the central districts of the city there are plenty job opportunities.

To enhance attractiveness of public transit and relieve pressure on street-and-road network from motor vehicles it is necessary to improve efficiency, comfortability and speed characteristics of the surface transport.

Organization of public transit priority in a city will enable to increase traffic speed and efficiency of operation. Bus rapid transit systems developed in foreign countries are not in practice in Russian cities nowadays, although this practice seems more efficient and faster as compared to construction of an underground rapid transit. This method allows to build-up a reliable and fast remote district connection with the centre of a city, and use it as a highway route.

To diminish a need to ride to the centre from remote districts every day, it is reasonable to build-up a respective social infrastructure and create jobs in close vicinity to the district of living.

All measures focused on improvement of public transit operation will enable to make it more comfortable and attractive to passengers, as well as reduce economic losses by transport businesses.

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